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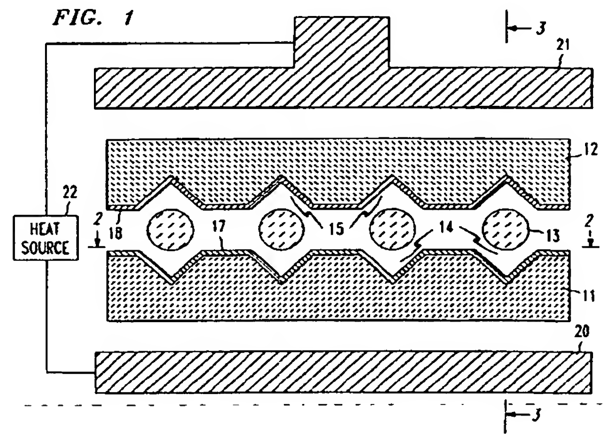
(54) Optical fiber bonding techniques.

(57) First and second V-grooves (14, 15) are respectively formed in first and second monocrystalline semiconductor elements (11, 12). Aluminum layers (17, 18) are formed in the first and second V-grooves, but each aluminum layer extends only along a portion of the length of its respective groove. An optical fiber (13) is located between the first and second grooves and is heated and compressed between the opposite first and second monocrystalline elements, the heat and pressure being sufficient to cause bonding between the aluminum layer and the optical fiber. By aluminizing only a portion of each groove, rather than its entire length, the compressive forces applied to the first and second monocrystalline elements are concentrated at the interface of the aluminum layer with the optical fiber. This increases the pressure between the optical fiber and the aluminum beyond that which would occur if the entire length of the V-grooves were aluminized. As a consequence, the bonding is reliable.

FIG. 1



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Technical Field

This invention relates to compression bonding methods and, more particularly, to methods for bonding optical fibers to aluminum coated substrates.

Background of the Invention

Optical communications systems commonly use optical fibers for carrying very large quantities of information with low distortion and low cost over great distances. Optical systems are also promising for such purposes as computing because of the inherently high speed at which they can be operated. For these reasons, considerable development work has been done on methods for packaging and connecting optical fibers.

For example, the U. S. patent of Bonanni, No. 4,818,058, granted April 4, 1989, and the U. S. patent of Bonanni et al., No. 4,998,796, granted March 12, 1991, hereby incorporated herein by reference, describe optical fiber connectors comprising silicon chips for holding in place a plurality of fibers of an optical fiber ribbon. Silicon is a monocrystalline material in which small V-grooves can be very accurately formed by photolithographic masking and etching. Optical fibers having a typical diameter of one hundred twenty-five microns can be held in place by matching opposite V-grooves that are each about one hundred microns deep and one hundred forty microns wide. The matching V-grooves of opposing silicon chips accurately position the fibers, the fibers being permanently held in place by an adhesive such as an epoxy.

The U. S. patent of Coucoulas, No. 5,178,319, granted January 12, 1993, hereby incorporated herein by reference, teaches that an optical fiber can be bonded within the V-groove of a silicon substrate by coating the V-groove with aluminum and applying heat and pressure. The resulting thermo-compression bond can securely contain the optical fiber within the V-groove, thus avoiding the need for an adhesive, which may contaminate other elements of a photonics package. It would appear that the Coucoulas invention could be routinely applied to the connector packages of Bonanni et al. so as to avoid the adhesive required in making the connectors described in the Bonanni patents. Experience has shown, however, that when the V-grooves of a connector such as that described in the Bonanni patents are aluminized, and the opposite silicon elements are compressed against heated optical fibers to make the bond, the resulting bond is sometimes not reliable. It appears that certain of the optical fibers are not sufficiently compressed into the aluminum coating to make a satisfactory bond, and the force needed to give reliable bonding along the lengths of a multiplicity of fibers has sometimes been found to be beyond that that can be exerted on the silicon chips. That is, if too much force is applied, the silicon chips may crack. There is therefore a continuing need in the industry for methods for more expediently and reliably bonding optical fibers to substrates and, more particularly, methods for expediently assembling optical fiber connectors using V-grooves etched in monocrystalline materials.

Summary of the Invention

In accordance with an illustrative embodiment of the invention, first and second V-grooves are respectively formed in first and second monocrystalline semiconductor elements. Matching aluminum layers are formed in the first and second V-grooves, but each aluminum layer extends only along a portion of the length of its respective groove. An optical fiber is located between the first and second grooves and is heated and compressed between the opposite first and second monocrystalline elements, the heat and pressure being sufficient to cause bonding between the aluminum layer and the optical fiber. By aluminizing only matching portions of the grooves, rather than their entire lengths, the compressive forces applied to the first and second monocrystalline elements are concentrated at the interfaces of the aluminum layers with the optical fiber. This increases the pressure between the optical fiber and the aluminum beyond that which would occur if the entire lengths of the V-grooves were aluminized. As a consequence, the bonding is reliable.

These and other objects, features and advantages of the invention will be better understood from a consideration of the following detailed description taken in conjunction with the accompanying drawing.

Brief Description of the Drawing

FIG. 1 is an exploded view of apparatus for assembling an optical fiber connector in accordance with one embodiment of the invention;

FIG. 2 is a view taken along lines 2-2 of FIG. 1; and

FIG. 3 is a view taken along lines 3-3 of FIG. 2.

Detailed Description

The drawings are only schematic, with certain dimensions being distorted to aid in clarity of exposition. Referring now to FIG. 1, there is shown an exploded view of apparatus for assembling an optical fiber connector assembly comprising first and second monocrystalline semiconductor chips 11 and 12 for containing therebetween a plurality of optical fibers 13. V-grooves 14 and 15 are respectively formed in chips 11 and 12 by photolithographic masking and etching in accordance with the principles described in the aforementioned Bonanni patent. The optical fib-

ers are typically only about one hundred twenty-five microns in diameter; the masking and etching can define the V-grooves 14 and 15 with great accuracy, so that opposite grooves precisely contain between them an optical fiber, as is required for aligning the fibers with other fibers, with lenses and the like.

In accordance with the principles described in the aforementioned Coucoulas patent, the V-grooves 14 and 15 are coated with layers 17 and 18 of aluminum. The optical fibers 13 are permanently bonded to chips 11 and 12 by compressing them between chips 11 and 12, using a tool having opposite press members 20 and 21. The press members are shown as being heated by a heat source 22. The purpose of the heat source is to heat the interface of the optical fibers 13 and the aluminum layers 17 and 18 as they are being compressed between press members 20 and 21. Alternatively, the heat could be applied to the chips 11 and 12, or the assembly shown could be contained within a furnace. The fibers are typically heated to a temperature of four hundred to four hundred fifty degrees Centigrade, and, with a sufficient pressure applied, will bond permanently to aluminum layers 17 and 18 without distorting and without damaging the monocrystalline chips 11 and 12.

In accordance with the invention, as shown in FIG. 2, the aluminum layer 17 covers only a portion of the length of each V-groove 14. In the example shown, the aluminum layer 17 covers only about one-third of the length of each V-groove 14. As shown in FIG. 3, the aluminum layer 18 matches the geometry of aluminum layer 17 so that it likewise covers only about one-third the length of each of the V-grooves 15, and lies on the side of the fiber 13 opposite layer 17. Making the aluminum layers 17 and 18 shorter than the lengths of grooves 14 and 15 has the effect of concentrating the forces applied by pressing members 20 and 21 to the aluminum layers 17 and 18. As a consequence, the pressure (force per unit of area) applied at the interfaces of aluminum layers 17 and 18 with the optical fibers 13 is greater than it would be if the aluminum were coated along the entire length of each V-groove.

In one experiment, the opposite chips each contained only a single V-groove which held between them a single optical fiber. The V-groove had a length of ten millimeters that was entirely coated with aluminum. The assembly was heated to four hundred to four hundred fifty degrees Centigrade, and a force of 2.5 kilograms was applied to the chips to compress the fiber between them. The compression was applied for five to ten seconds. There was no bonding.

An identical pair of chips having matching V-grooves ten millimeters long were coated with aluminum only over two to two and one-half millimeters of the lengths of the V-grooves. The assembly was again heated to four hundred to four hundred fifty degrees Centigrade. Instead of 2.5 kilograms, a force of only five hundred grams was applied to compress the chips for five to ten seconds. This was found to give a reliable bond along the entire length of the aluminized portion of the V-grooves. Thus, a force of only one-fifth the force used in the unsuccessful experiment gave reliable bonding.

We have not done a detailed analysis of the relationship between the concentration of forces and the effectiveness of the bond. There does, however, appear to be a roughly linear correlation between the reduction of the length of the groove that is aluminized with the reduction of force required for making a bond. Thus, for example, if one reduces the length of the groove that is aluminized by eighty percent, it appears that one can use eighty percent less force in making the bond because of the concentration of the forces as described above. If less than half of the lengths of the grooves are aluminized, only half the force otherwise required can be used to make reliable bonds. This is significant because monocrystalline silicon cannot withstand excessive force, and if many grooves and many fibers were to be bonded simultaneously, it is difficult to apply sufficient force for r liable bonds if there is not a concentration of forces in accordance with the invention. The invention also allows more deviation of the parallel configuration of press members 20 and 21. That is, without the invention, slight deviations from a precisely parallel configuration will give a maldistribution of forces on the fibers that may crack the silicon or may leave certain fibers unbonded.

While the invention is particularly applicabl to structures of the type described in the Bonanni patent, using V-grooves for supporting glass optical fibers, it is potentially useful in other configurations as well. As mentioned in the Coucoulas patent, acoustic energy can be applied to the glass-aluminum interface, rather than heat, to permit the compression bonding. The invention could be used to aid in bonding fibers to horizontal surfaces. Other embodiments and modifications may be made by those skilled in the art without departing from the spirit and scope of the invention.

Claims

1. A method for bonding an optical fiber to a member coated with aluminum comprising the steps of:

    coating part of the member with aluminum;

    positioning the optical fiber on the aluminum surface;

    and simultaneously pressing together the optical fiber and the aluminum, and applying energy to the interface of the optical fiber and the aluminum so as to make a permanent bond between the optical fiber and the aluminum, characterized by:

coating with aluminum only a portion of the member with which the optical fiber makes contact;

and applying force to a greater length of the optical fiber than is in contact with the aluminum, thereby to concentrate such force at the interface of the optical fiber with the aluminum.

2. The method of claim 1 wherein:

less than half the length of the member with which the optical fiber makes contact is coated with said aluminum;

and the force is applied to the optical fiber along the entire length of the member.

3. The method of claim 2 wherein:

the portion of the member with which the optical fiber makes contact has the configuration of a V-shaped groove for containing the optical fiber.

4. The method of claim 3 wherein:

the step of applying the force to the entire length of the optical fiber comprises the step of forcing against the optical fiber a V-shaped groove in a second member, a portion of the V-shaped groove in the second member being coated with aluminum to match the coating of aluminum on the first member.

5. The method of claim 4 wherein:

the first and second members are each made of a monocrystalline semiconductor material;

and the first and second V-grooves are made by photolithographic masking and etching.

6. The method of claim 5 wherein:

the energy applied is heat energy.

7. The method of claim 5 wherein:

a plurality of first and second V-grooves are respectively formed in the first and second monocrystalline members;

a separate optical fiber is compressed between each pair of first and second V-grooves;

and the step of forming the aluminum layer comprises the step of forming the layer as a continuous strip that extends transversely to the V-grooves.

8. The method of claim 7 wherein:

the aluminum strip has a thickness of three to fiv microns and a width of about 2.5 millimeters;

and the first and second V-grooves each have a length of about ten millimeters.

9. The method of claim 8 wherein:

the location of the aluminum layer in the first V-groove matches the location of the aluminum layer in the second V-groove;

and the lengths of the aluminum layers in the first and second V-grooves are each less than half the length of the first or second V-groove.

10. The method of claim 9 wherein:

the first and second members are silicon chips;

and the compressing step comprises the step of compressing the silicon chips between opposite press members that have been heated.

FIG. 1

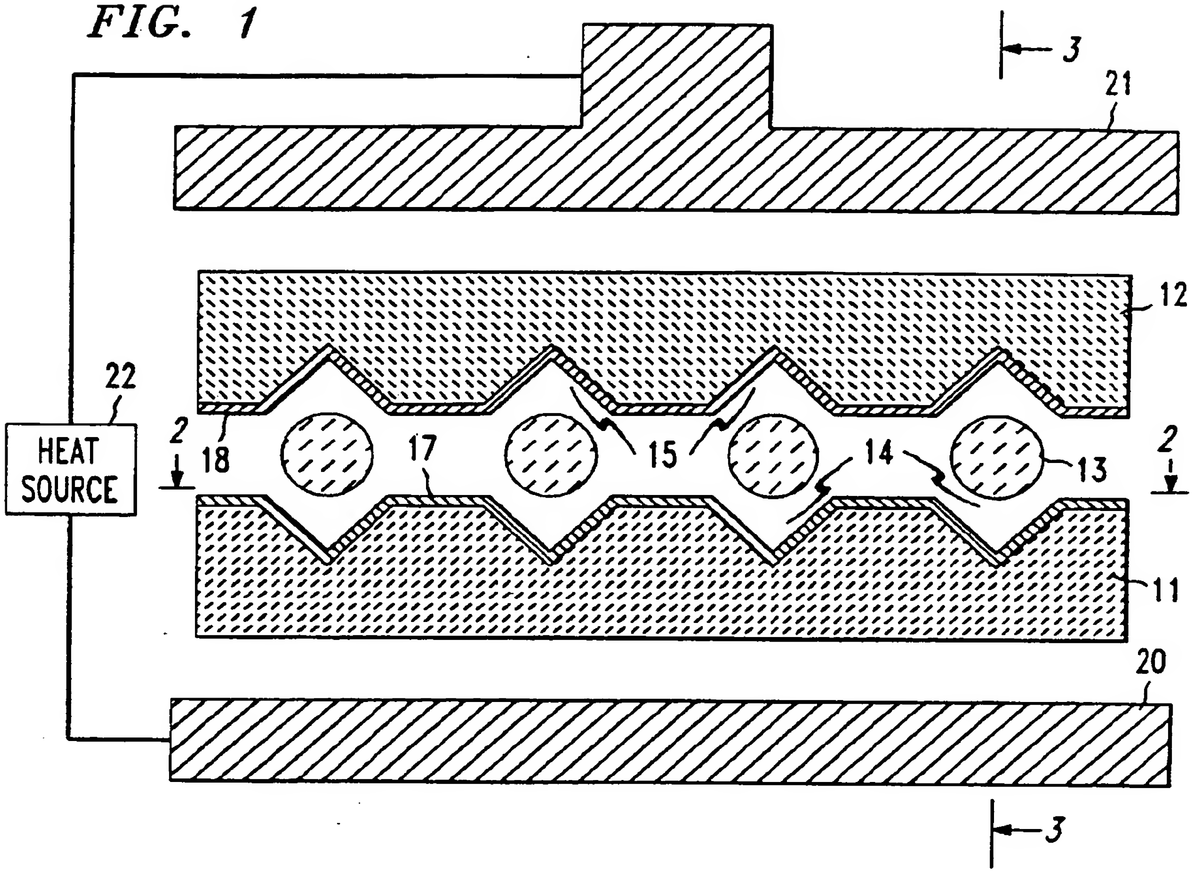


FIG. 2

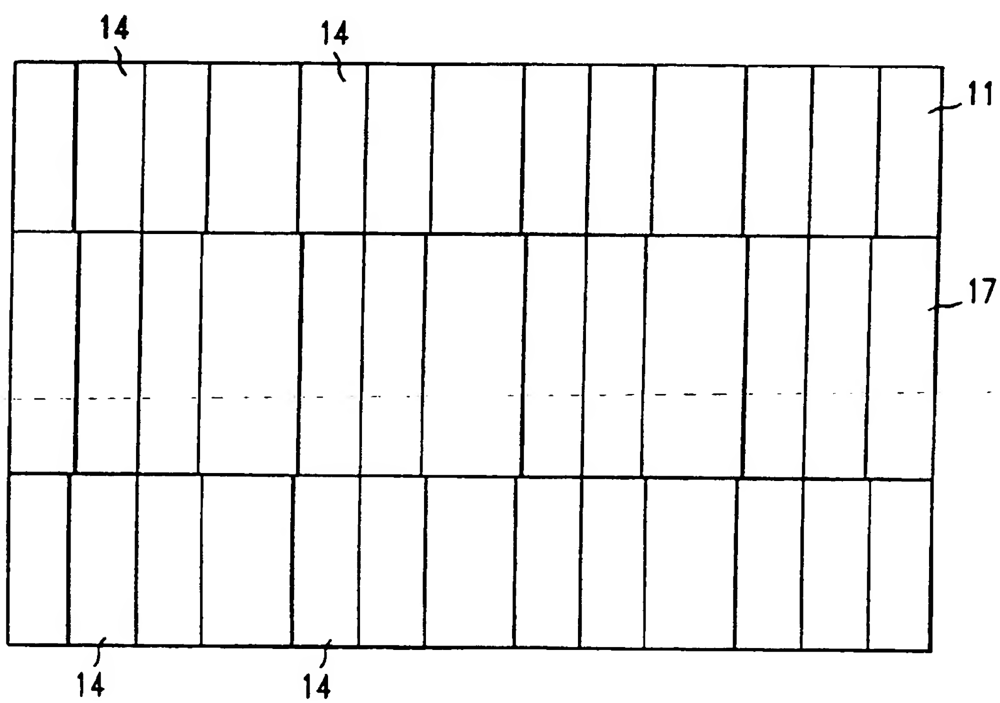
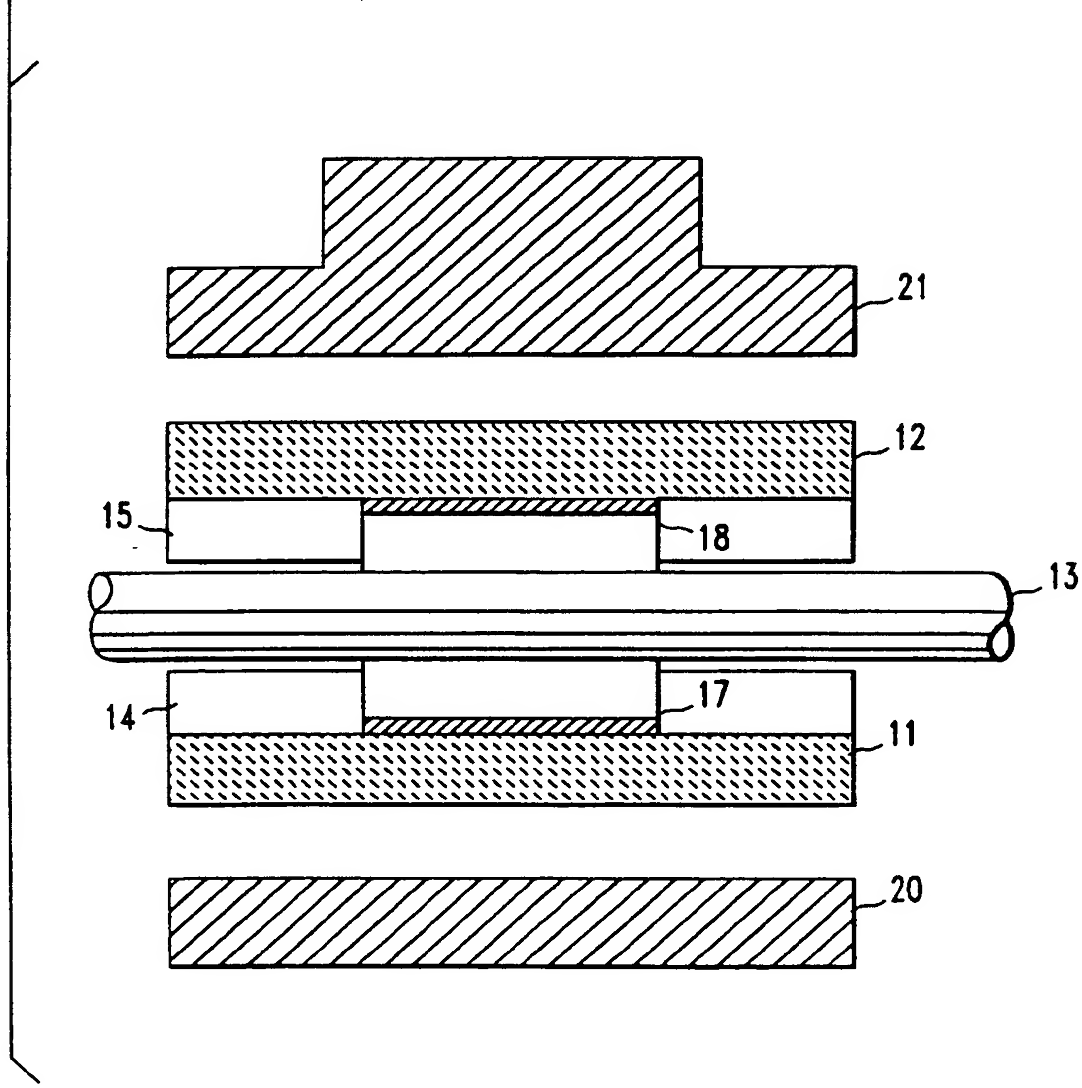


FIG. 3



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EUROPEAN SEARCH REPORT

Application Number
EP 94 30 4329

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	EP-A-0 542 444 (AMERICAN TELEPHONE & TELEGRAPH COMPANY) * column 3, line 1 - line 25 * * column 4, line 20 - line 41; claims 3,4,6,10; figure 5 *	1	G02B6/38 G02B6/42
A		3-6,10	
D,A	US-A-5 178 319 (A.COUCOULAS) * column 1, line 44 - line 66 * * column 3, line 38 - line 49; claims 2-4,6,7,11; figures 3,4 *	1,3,5,6	
A	EP-A-0 529 953 (AMERICAN TELEPHONE & TELEGRAPF COMPANY) * abstract; figures 2,4 * * column 3, line 27 - line 42 *	1	
A,D	US-A-4 818 058 (R.BONANNI) * abstract; claims; figures 1-3 *	1,3-5,7	
A	DE-A-34 43 693 (STANDARD ELECTRIC LORENZ AG) * abstract; figure 2 *	3,4,7	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
A	DE-A-38 10 044 (SIEMENS AG) * abstract; figure 4 *	2,3,7	G02B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	4 October 1994	Hylla, W

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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